EIGHT

WORKER AND EQUIPMENT DECONTAMINATION

8.1 BACKGROUND

Decontamination of workers and equipment as part of hazardous waste activities at Department of Energy (DOE) sites requires consideration of worker health and safety, project budget and schedule, generation of additional waste, and periodic equipment replacement. Thus, it is imperative for project managers to apply a systems-based philosophy in planning and conducting decontamination activities.

Anything that enters a radiological area, an airborne radioactivity area, or a hazardous waste exclusion zone is assumed to be contaminated. If not removed, contaminants eventually permeate the personal protective equipment (PPE), tools, instruments, and other equipment being used at the worksite and may be transferred into clean areas. Decontamination is the process of removing or neutralizing chemical, radiological, biological, or mixed waste contaminants (or all contaminants) that accumulate on personnel and equipment while work is being performed.

The time required for decontamination is to be incorporated into work plans and schedules. Contamination control and decontamination strategies and procedures are documented in the health and safety plan (HASP), communicated to workers, and implemented before workers enter areas where there is a potential for exposure to contaminants.

Appropriate procedures are developed and implemented to minimize contamination, to prevent its spread, and to decontaminate workers and equipment when they exit contamination areas. Contamination control and decontamination procedures depend on the type and source of contaminants, the level of contamination, and the severity of the hazards posed, as well as on the evaluation of worksite hazards and the job tasks to be performed. Contamination control and decontamination processes specified in the HASP are to be periodically evaluated for effectiveness and modified to correct deficiencies and address changing conditions and activities at the worksite.

> Contamination control and decontamination are crucial for protecting worker health and safety, the public, and the environment during DOE hazardous waste activities.

8.2 OVERALL DECONTAMINATION STRATEGY

Figure 8-1 outlines the decontamination strategy for workers and equipment. It includes documentation of the approach, decontamination methods, testing for decontamination effectiveness, location and configuration of the decontamination area, emergency decontamination procedures, identification of decontamination hazards, protection of decontamination workers, disposal methods, equipment decontamination, sanitation, and waste minimization.

DOCUMENTATION OF DECONTAMINATION APPROACH

Decontamination protocols are designed to remove hazardous substances from workers, their PPE, and other equipment exiting worksite contaminated areas (e.g., radiologically controlled area, exclusion zone). A protocol could be as simple as doffing PPE and placing it into appropriate containers for disposal or decontamination; each protocol specifies what personal hygiene practices (from simple handwashing through full onsite showering) are necessary, depending on the type and degree of the hazard. The HASP specifies the level of

EIGHT: WORKER AND EQUIPMENT DECONTAMINATION

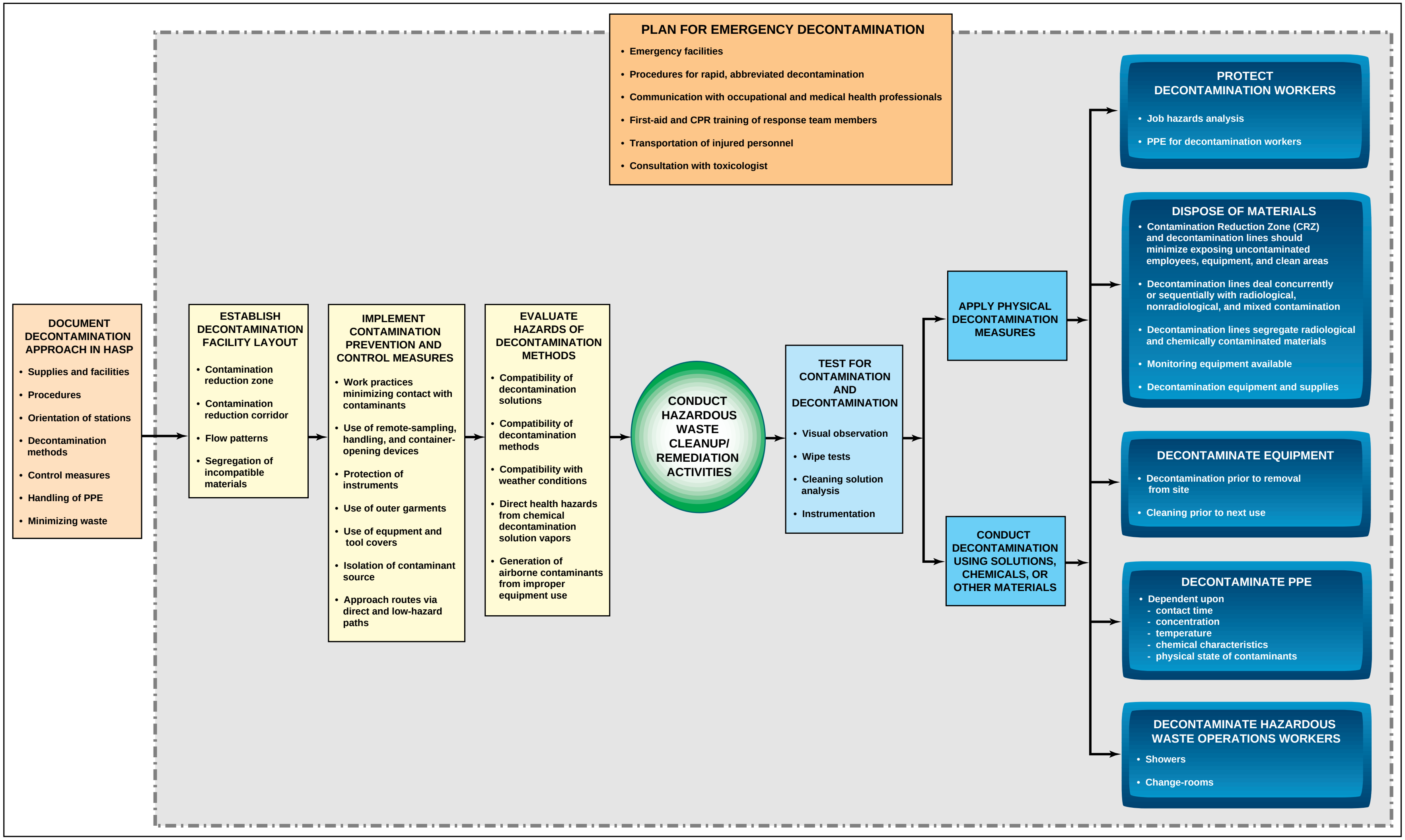

Figure 8-1. Overall Decontamination Strategy

decontamination necessary for workers and equipment at the worksite. Various methods of cleaning, neutralizing, or otherwise removing contaminants from workers, PPE, and other equipment are evaluated for use. Decisions concerning decontamination approaches should be based on the extent of worksite-specific hazards and activities. If not already specified in the HASP, all aspects of the decontamination approach and overall program should be documented in a decontamination plan. This plan should address:

- The number and layout of decontamination stations;
- Decontamination equipment needed;
- Appropriate decontamination methods;
- Procedures to prevent contamination of clean areas;
- Methods and procedures to minimize worker contact with contaminants during removal of PPE;
- Methods for disposing of clothing and equipment that are not completely decontaminated;
- Incompatible wastes requiring separate decontamination stations; and
- The target level of decontamination.

An essential part of the plan should address standard operating procedures (SOPs) for site operations that minimize contact with waste and thereby prevent the contamination of workers and equipment. Examples of such SOPs include:

- Work practices that minimize contact with hazardous substances;
- Use of remote sampling, handling, and container-opening techniques;
- Protection of monitoring and sampling instruments by bagging (openings can be made in the bags for sample ports and sensors that are required to physically contact worksite materials);
- Wearing disposable outer garments and using disposable equipment where appropriate;
- Covering equipment and tools with a strippable coating that can be removed during decontamination; and
- Encasing the source of contaminants with, for example, plastic sheeting or overpacks.

DECONTAMINATION METHODS

DOE worksites may contain radiological as well as mixed and traditional chemical or biological wastes or both. To prevent the further generation of mixed wastes, decontamination methods are carefully chosen and implemented. Contaminants can be deposited on the surface of or, in some instances, can permeate PPE and other equipment (see Figure 8-2). Most surface contamination is detected and removed by accepted decontamination practices. If, however, a contaminant has permeated the PPE (e.g., the fabric of coveralls), it may be difficult to detect and remove. When contaminants are allowed to remain in contact with materials (e.g., PPE, tools, instruments) for an extended period, those materials are particularly prone to permeation or degradation or both. The chemical and physical compatibility of decontamination solutions and methods with selected PPE is determined before use.

Contact time. The longer a contaminant is in contact with an object, the greater the probability and extent of permeation. Minimizing contact time is one of the most important objectives of a decontamination program.

Concentration. As concentrations of contaminants increase, the potential for permeation of PPE increases.

Temperature. Temperature increases generally increase the contaminant permeation rate.

Chemical characteristics. Permeation rates are dependent on the molecular or particulate size of the contaminant and on the pore space of the protective material. Chemical characteristics (e.g., polarity, vapor pressure, pH) of both the contaminant and the protective material determine permeability.

Physical state of contaminants. Gases, vapors, and low-viscosity liquids tend to permeate more readily than high-viscosity liquids or solids.

Figure 8-2. Major Factors Affecting Contaminant Permeation of PPE and Other Equipment

Decontamination by Physical Means. Some contaminants encountered are removed by physical means (e.g., washing, brushing, scraping, using sticky tape, rinsing, heating) that dislodge or displace the contaminant. Caution should be used, however, when selecting physical methods involving high pressure or heat since these methods can produce aerosols or cause burns. Weather conditions should be considered when choosing physical decontamination methods.

Contaminants that are physically removed fall into four major categories:

- *Loose Contaminants*. Dusts and aerosols that cling to equipment and workers or become trapped in small openings (e.g., in the weave of fabrics) can be removed with sticky tape, water, or a liquid rinse. Removal of electrostatically attached material is enhanced by coating clothing or equipment with antistatic solutions. Chemicals can be complexed (e.g., metals precipitation) and removed using specially designed vacuums equipped with high-efficiency particulate air (HEPA) filters and other system controls; asbestos fibers can be removed using similar devices. In some cases, elemental mercury can be removed using special mercury vacuums.

- *Adhering Contaminants*. Removal is often enhanced through methods such as solidification, freezing (e.g., with ice or dry ice), adsorption or absorption (e.g., with powdered lime or kitty litter), or melting with a low-energy heat source (e.g., hair dryer or heat lamp).

- *Adsorbed or Permeated Contaminants*. In some cases, contaminant removal is not possible and the PPE, tools, instruments, or other equipment has to be discarded as additional hazardous waste. Care in selecting PPE and in applying contamination prevention and control measures, along with timely and appropriate decontamination measures, often prevents this situation.

- *Volatile Liquids*. Volatile liquid contaminants can be removed from protective clothing or equipment by evaporation followed by a water rinse. Evaporation of volatile liquids can be enhanced by using steam jets. With any evaporation or vaporization process, care must be taken to prevent worker inhalation of vaporized chemicals.

Decontamination Using Solutions, Chemicals, and Other Materials. Physical removal of chemical or radiological contamination or both should always be followed by washing or rinsing. Steam (for equipment) or hot water with detergent is the preferred decontamination method. In some cases, it may be necessary to use a special solution or combination of solutions to decontaminate thoroughly. The site safety and health officer (SSHO) consults with health physicists, chemists, or toxicologists, or all three, for selection of the safest and most effective decontamination solutions for the specific contaminants. Cleaning solutions normally use one or more of the following methods:

- *Dissolving contaminants*. Chemical removal of surface contaminants can be accomplished by dissolving them in a solvent. The solvent must be chemically compatible with the equipment being cleaned. This is particularly important when decontaminating protective clothing constructed of organic materials that could be damaged or dissolved by organic solvents. Care must be taken in selecting, using, and disposing of any organic solvents that may be flammable or potentially toxic. Organic solvents include alcohol, ethers, ketones, aromatics, straight-chain alkanes, and common petroleum products. Halogenated solvents generally are incompatible with PPE and are toxic. They should only be used for decontamination in extreme cases where other cleaning agents will not remove the contaminant.

- *Surfactants*. Surfactants augment physical cleaning methods by reducing adhesion forces between contaminants and the surface being cleaned, and by preventing redeposition of the contaminants. Household detergents are among the most common surfactants. Some detergents can be used with organic solvents to improve the dissolving and dispersal of contaminants into the solvent.

- *Solidification*. Solidifying liquid or gel contaminants can enhance their physical removal. The mechanisms of solidification are (1) moisture removal through the use of adsorbents such as ground clay or powdered lime, (2) chemical reactions via polymerization catalysts and chemical reagents, and (3) freezing using ice water.

- *Rinsing*. Rinsing removes contaminants through dilution, physical attraction, and solubilization. Multiple rinses with clean solutions remove more contaminants than a single rinse with the same volume of solution. Continuous rinsing with large volumes of clean solutions will remove even more contaminants than multiple rinsings with a lesser total volume.

- *Disinfection/Sterilization*. Chemical disinfectants are a practical means of inactivating infectious agents. Standard sterilization techniques are generally impractical for large equipment and for PPE. For this reason, disposable PPE is recommended for use with infectious agents.

The SSHO consults with industrial health and safety chemists or toxicologists or both for selection of the safest and most effective decontamination solutions for the specific contaminants. Selection is influenced by health and safety hazards posed by the decontamination method, effectiveness of the decontamination method, ease of implementation, availability, and cost.

TESTING FOR DECONTAMINATION EFFECTIVENESS

The effectiveness of any decontamination method must be assessed at the beginning of a project and periodically throughout the conduct of the project. If contaminants are not being removed or are penetrating protective clothing, the decontamination program must be revised. Methods useful in assessing the effectiveness of decontamination include the following:

Visual Observation. Visual observation involves use of natural light and ultraviolet light. In natural light, discolorations, stains, corrosive effects, visible dirt, or alterations in clothing fabric may indicate that contaminants have not been removed. In ultraviolet light, certain contaminants (e.g., polycyclic aromatic hydrocarbons, which are common in many refined oils and solvent wastes) fluoresce and can be detected visually. Ultraviolet light can be used to observe contamination of skin, clothing, and equipment. A qualified health professional should be consulted prior to the use of this technique, since certain areas of the skin may fluoresce naturally and introduce uncertainty into the test. Also, use of ultraviolet light can increase the risk of skin cancer and eye damage.

Wipe Sampling. Wipe sampling involves swiping a dry or wet cloth, glass fiber filter paper, or swab over the surface of a potentially contaminated object and performing a laboratory analysis. Both the inner and outer surfaces of protective clothing should be tested to check for permeation. Skin can also be tested using this method.

Cleaning Solution Analysis. Analysis of contaminants left in cleaning (or final rinse) solutions may indicate that additional cleaning and rinsing are necessary.

Permeation Testing. Testing for the presence of permeated chemical contaminants requires that pieces of the protective garments be sent to a laboratory for analysis.

LOCATION AND CONFIGURATION OF DECONTAMINATION AREA

Decontamination for hazardous waste activities is conducted in the contamination reduction corridor (CRC) within a well-defined contamination reduction zone (CRZ) or radiological buffer area. The CRC is analogous to the entryway and decontamination passageway established for a radiologically controlled area, and the design concepts used are the same (see Chapter 7). Decontamination equipment, processes, and procedures vary, as do contamination reduction zones and corridors, depending on the presence of specific hazards and the size and complexity of the worksite and project. Modifications to the location and configuration of the decontamination area may be required to accommodate changing conditions (e.g., wind) at the worksite.

Location and Size of CRZ/C

The location and size of the Contamination Reduction Zone/Corridor (CRZ/C) for most DOE hazardous waste activities projects depends on the amount of space available at the worksite, the use of large equipment, the number of stations necessary for the decontamination procedure, and the overall dimensions of the work zones. For some activities, wind direction is an important consideration in selecting the best location and layout for the CRZ/C (i.e., they remain upwind of the contaminated areas of the worksite).

The number of decontamination stations and the sequence of steps to be followed during decontamination constitute the decontamination line and are clearly defined in the HASP. The proper selection and donning of PPE is of particular importance in preventing worker contamination during the decontamination process. Procedures for properly donning and doffing protective clothing are implemented before workers enter controlled areas. These procedures are detailed in the HASP, thereby preventing worker contamination and facilitating the safe decontamination of PPE as workers go through the decontamination process. For radiological decontamination, use of two step-off pads may be recommended (see the *Draft DOE Radiological Control Technical Standard*).

The following aspects should be considered in establishing the configuration of the CRZ/C:

- Outer, more heavily contaminated items (e.g., outer boots and gloves) should be decontaminated first, followed by decontamination and removal of inner, less contaminated items (e.g., jackets and pants);
- Each procedure should be performed at a separate station to prevent cross contamination;
- Stations should be physically separate and should be arranged in order of decreasing contamination, preferably in a straight line;
- Separate flow patterns and stations should be provided to isolate workers from different contamination zones containing incompatible wastes;
- Dressing stations for entry to the CRZ should be separate from redressing areas for exit from the CRZ; and
- Workers should always pass through doffing stations for respiratory protective equipment only after their garments are removed to maximize respiratory protection while decontaminating.

A worker who has inhaled **harmful levels of** chemical contaminants should be removed from the area and receive emergency medical treatment while he or she awaits treatment by a physician. If the contaminant is on the skin or in the eyes, immediate measures should be taken to remove and counteract its effects. First-aid treatment usually involves flooding the affected area with clean water for at least 15 minutes. For a few chemicals, however, water may cause more serious problems. The HASP should anticipate and contain procedures for dealing with such possibilities.

EMERGENCY DECONTAMINATION PROCEDURES

The multidisciplinary team plans for both routine and emergency decontamination and documents the plans in the HASP. To prevent the possibility of decontamination causing serious health effects or aggravating existing illnesses or injuries, methods are to be established for decontaminating workers with medical problems or injuries. When protective clothing is grossly contaminated, it is possible that contaminants can be transferred to either emergency medical personnel or the wearer. Unless severe medical problems have occurred simultaneously with gross contamination events, PPE is quickly washed off and carefully removed.

Lifesaving Care

Lifesaving care is to be instituted immediately without considering decontamination. Difficulty in breathing, cardiac arrest, arrhythmias, heatstroke, and severe bleeding must be treated as quickly as possible. In addressing life-threatening circumstances, the following actions are to be considered:

- Outer garments and PPE may be removed depending on injury, weather conditions, delays, interference with treatment, or aggravation of the problem. Respirators and backpack assemblies should be removed. Fully encapsulating suits or chemical-resistant clothing can be cut away.

- If removal of contaminated garments will cause further injury, the individual should be wrapped in plastic, rubber, or blankets to prevent contamination of medical personnel and equipment. Contaminated garments should be removed at a medical facility, and carefully handled and contained to prevent or minimize cross-contamination.

- No attempt should be made to wash or rinse the victim at the worksite unless the individual is known to be contaminated with an extremely toxic or corrosive material that could cause further severe injury or loss of life. For minor medical problems or injuries, normal decontamination procedures are to be followed.

IDENTIFICATION OF DECONTAMINATION HAZARDS

Decontamination of PPE reduces exposures and protects worker health and safety. However, physical and chemical decontamination methods may themselves be hazardous. Methods that permeate, degrade, damage, or reduce PPE effectiveness are to be avoided. PPE, sampling instruments, tools, and other equipment are usually decontaminated by scrubbing with solutions of detergent and water, using soft-bristle brushes, followed by rinsing with water. Though this process may not remove all contaminants completely (or in a few cases, contaminants may react with water), it is safer than using harsh chemicals.

Potential decontamination hazards include, but are not limited to, the following:

- Incompatibility between decontaminating agents and contaminants;

- Incompatibility between decontaminating agents and clothing or equipment being decontaminated;

- Potential effects of inclement weather (e.g., using wet procedures during cold weather can cause both operational and maintenance problems);

- Potential effects of hazards on worker health and safety (e.g., vapors from chemical decontamination solutions may be hazardous on inhalation or contact with skin, or may be flammable); and

- Generation of airborne contaminants from improper use of equipment (e.g., jet sprayers, vacuum cleaners).

PROTECTION OF DECONTAMINATION WORKERS

For many operations, workers are assigned to assist in conducting decontamination of workers wearing Level A or B PPE during the decontamination process. Decontamination workers stationed at the front end of the decontamination line may require more protection from chemical and radiological contaminants than decontamination workers assigned to the latter stages of decontamination.

> Job, task, and hazard analysis is conducted and hazards associated with the decontamination process identified to determine appropriate types of PPE for decontamination workers. This information is incorporated in the HASP, the radiological work permit, or the safe work permit or plan.

In some cases, decontamination workers wear the same level of PPE as workers entering the radiologically controlled area or exclusion zone. In others, decontamination workers are sufficiently protected by wearing a lower level of PPE. Level D is not acceptable in the CRZ for decontamination line personnel. All decontamination workers must themselves be decontaminated before entering the support zone. Appropriate equipment and clothing for protecting decontamination workers are planned for by the multidisciplinary team, which includes workers and health professionals.

DISPOSAL METHODS

Before other operations begin, all materials used in the decontamination of workers and equipment are decontaminated and properly disposed of. Materials used for decontamination are regarded as hazardous, radioactive, or mixed waste until surveyed and released. Buckets, brushes, clothing, tools, and other contaminated equipment are collected and labeled appropriately. Yellow plastic wrapping material is used for packaging radioactively contaminated material. Yellow plastic sheets or bags are ***not*** to be used for nonradiological purposes. Care must be taken to avoid placing waste streams of incompatible contaminants together in the same container and to emphasize waste minimization methods whenever possible.

EQUIPMENT DECONTAMINATION

Although avoiding contamination is preferred, some equipment used in remedial actions or sampling becomes contaminated. These items are either properly decontaminated before being removed from the site or, in the case of drilling tools, thoroughly cleaned before the next use. Disposable plastic tarpaulins can be used to minimize the need for subsequent cleaning. Particular care must be given to such elements as tracks, tires, shovels, grapples, and scoops that come into direct contact with contaminants.

> The duration of and methodology selected for decontamination are determined by a thorough inspection of equipment, supplemented by frisking or a wipe test. All equipment parts are thoroughly cleaned. Air filters are to be considered highly contaminated, removed, and replaced before the equipment leaves the worksite. Porous items (e.g., wooden truck beds, cloth hoses, wooden handles) usually cannot be thoroughly cleaned and must be discarded.

Decontamination of vehicles and large pieces of equipment (e.g., pumps) is typically conducted on a wash-pad constructed so that cleaning solutions and wash-water are recycled or collected for later disposal. Similarly, equipment being dry-brushed or vacuumed with specially filtered vacuums is placed on a nonporous pad to facilitate containment and waste collection. Decontamination starts with the simplest methods likely to be effective (e.g., a general wet spraying to remove most of the contamination followed by scrubbing more difficult areas). By following procedures such as these, workers are able to minimize unnecessary contact with contaminated equipment.

Steam-cleaning and pressure-spraying using water mixed with a general-purpose, low-sudsing soap or detergent to improve wetting are the preferred methods for wet decontamination. Scrubbing with disposable or easily decontaminated brushes may be necessary to loosen materials. In most instances, hot water is more effective than cold. Flushing should be done under high pressure, taking care not to damage dials, gauges, wires, or hoses. Power-spraying is often more effective for such items as shovels, loaders, and scoops. Dry removal of contaminants can be accomplished through brushing, vacuum cleaning, vacuum blasting, and sandblasting. Vacuum cleaning with high-efficiency filtered units mounted over 55-gallon recovery drums provides the best control mechanism for fugitive emissions.

Recommended equipment for decontamination of (1) personnel, (2) PPE, (3) heavy equipment, and (4) vehicles is identified in the *Occupational Safety and Health Guidance Manual for Hazardous Waste Site Activities*.

SANITATION

The concepts of sanitation and decontamination are sometimes confused. Sanitation is the promotion of general public health by controlling sewage, protecting the cleanliness of drinking water, and promoting personal hygiene. Decontamination involves eliminating or deactivating either radiological or nonradiological contaminants and preventing the migration of hazardous constituents outside the worksite boundaries.

Many hazardous waste activity worksites are temporary and are established at remote locations with limited sanitation facilities. For jobs lasting 6 months or longer, showers and two-stage change-rooms are provided in accordance with 29 CFR 1910.141 (d). These, of course, are designed to accommodate both genders, as necessary.

Access to emergency showers and eyewashes is part of the site-specific emergency response and medical first-aid programs, and is unrelated to sanitation or decontamination. Requirements for the availability and location of emergency showers and eyewashes are specified under 29 CFR 1910.151.

> Decontamination is conducted either in the contamination reduction zone or the radiological buffer zone at the worksite, whereas sanitation functions are performed either in the support zone or outside the boundaries of the hazardous waste activities worksite after decontamination has been completed.

The HAZWOPER Standard requires employers to make certain that when showers are a necessary step in the decontamination process, "their employees shower at the end of their work shift and when leaving the hazardous waste site." Sanitation-related showers (unlike decontamination showers) are understood to be voluntary. Decontamination and emergency showers must be located close to the worksite. Sanitary showers may be located at some distance from the worksite.

WASTE MINIMIZATION

Although waste minimization is not explicitly part of the range of activities addressed in the HAZWOPER Standard, it nevertheless represents a management practice that supports worker and equipment decontamination. Waste minimization practices decrease project costs (through reduced storage and transportation requirements), reduce worker exposures, and decrease the overall infrastructure required for decontamination. In addition, DOE is committed to minimizing waste generated within DOE operations. This includes hazardous waste operations.

8.3 REFERENCES

10 CFR 71, "Packaging Radioactive Materials for Transport"

29 CFR 1910.120, "Hazardous Waste Operations and Emergency Response"

29 CFR 1910.141, "Sanitation"

29 CFR 1910.151, "Medical Services and First Aid"

40 CFR 243, 260-267, "EPA Guidelines for Solid Waste Storage and Collection"

40 CFR 761, "EPA Regulations on PCBs"

49 CFR 100-179 and 397, "DOT Hazardous Materials Regulations"

DOE O 231.1, "Environment, Safety, and Health Reporting"

DOE O 460.1, "Packaging and Transportation Safety" -- CHANGE 001

DOE O 460.2, "Departmental Materials Transportation and Packaging Management" -- CHANGE 001

DOE 5400.1, "General Environmental Protection Program"

DOE 5480.3, "Safety Requirements for the Packaging and Transportation of Hazardous Materials, Hazardous Substances, and Hazardous Wastes" [except for portions canceled by DOE O 231.1]

DOE 5820.2A, "Radioactive Waste Management"

DOE SEN-37-92, "Waste Minimization Crosscut Plan Implementation"

DOE-STD-1098-96, *Draft DOE Radiological Control Technical Standard*

NIOSH/OSHA/USCG/EPA, *Occupational Safety and Health Guidance Manual for Hazardous Waste Site Activities*